Ocean FEST: Families Exploring Science Together

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ABSTRACT

This project engages elementary school students, parents, teachers, and administrators in ocean-themed family science nights based on a proven model. Our key goals are to: (1) educate participants about ocean and earth science issues that are relevant to their communities; and (2) inspire more underrepresented students, including Native Hawaiians, Filipinos, Pacific Islanders, and girls, to pursue careers in the ocean and earth sciences. Hawaii, the Pacific Islands, and Pacific Rim nations will be disproportionately affected by the impacts of global climate change, including rising sea levels, coastal erosion, coral reef degradation, and ocean acidification. Therefore, it is essential to train local geoscientists in these communities. Although designed for Hawaii's students in grades 3–6 and their families, this ocean-themed program can be effective with a range of audiences. © *2011 National Association of Geoscience Teachers*. [DOI: 10.5408/1.3543933]

INTRODUCTION

Hawaii is the most isolated archipelago in the world, with a unique natural and cultural landscape (Morgan, 1996). Hawaii's major industries are tourism and agriculture, with only a small fraction of residents employed in science, technology, engineering and mathematics (STEM) fields. However, that is about to radically change. In 2007, Governor Linda Lingle signed the Hawaii Innovation Initiative, a critical piece of legislation designed to transform the state's economy to one based on innovation by developing Hawaii's human capital. Central to this initiative is Act 111, which allocates significant state general funds for K–12 STEM education (DBEDT, 2008) beginning in 2009. Thus, now is the time for innovative, hands-on science in Hawaii.

Marine science is particularly relevant and attractive to Hawaii's students, and the marine science subfield that has expanded most rapidly in recent years is microbial oceanography, largely due to the growing recognition of the critical influence of microbes in modulating the earth's climate (Azam *et al.*, 1983; Waterbury *et al.*, 1979). The past decade has seen a sharp increase in programs devoted to microbial oceanography, including the creation of the Center of Microbial Oceanography: Research and Education (C-MORE), a National Science Foundation-sponsored Science and Technology Center. Based at the University of Hawaii at Manoa (UHM), C-MORE scientists research the influence of marine microbes on global processes such as climate change. Moreover, marine sciences have played a central role in the management and protection of large marine ecosystems. The Hawaii Institute of Marine Biology (HIMB) Northwestern Hawaiian Islands Research Partnership with the National Marine Sanctuary Program is an excellent demonstration of this.

The potentially bright future of microbial oceanography (Kirchman and Pedrós-Alió, 2007) and related fields in marine science critically depends upon a continued influx of highly motivated young scientists, at a time when the potential pool of students in the sciences is declining (Snyder, 2003; National Academies Committee on Science Engineering and Public Policy, 2007). This situation is projected to worsen in upcoming years, as white males, who constituted 70% of the 1997 STEM workforce, are projected to represent only 26% of the overall workforce by 2050 (Day, 1996; AAAS 2001). Ensuring that there are enough STEM graduates clearly requires that we broaden participation among underrepresented groups (NSF Strategic Plan, http://www.nsf.gov/nsf/nsfpubs/straplan/meeting.htm#develop). This is particularly essential in the geosciences, which has the lowest rates of minority participation among all physical sciences (NSF, 2004; Riggs and Alexander, 2007). Of the 601 U.S. doctoral degrees awarded in the ocean and earth sciences in 2006, only a small fraction were earned by minority U.S. citizens or permanent residents: 23 Asian/Pacific Islander, 3 Black, 12 Hispanic, 0 American Indian/Alaska Native, and 23 other/unknown (NCES, 2006).

Nowhere is broadening participation more critical than in Hawaii, the most ethnically diverse state in the nation: Caucasian (24%), Japanese (20%), Native Hawaiian (19%), Filipino (11%), Chinese (5%), and others (21%) (Juvik and Juvik, 1998). Not surprisingly, virtually all campuses in the University of Hawaii (UH) system are minority serving institutions, partly due to the high enrollment of Native Hawaiians, Filipinos and Pacific Islanders (NHFPI). However, these students are not studying earth and ocean science. Of the 357 students enrolled in the three majors of the UHM School of Ocean and Earth Science and Technology (SOEST) during the 2007–2008 academic year, only 13 are NHFPI and only one is a graduate student; females are also notably underrepresented (UH Institutional Research Office, unpublished data).

Ocean FEST (families exploring science together) has two key goals: (1) educate participants about ocean and earth science issues that are relevant to their communities; and (2) inspire more underrepresented students, including Native Hawaiians, Filipinos, Pacific Islanders, and girls, to pursue careers in the ocean and earth sciences (see Table I for a summary of student demographics at Ocean FEST schools). Hawaii, the Pacific Islands, and Pacific Rim nations will be disproportionately affected by the impacts of global climate change, including rising sea levels, coastal erosion,

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TABLE I: Student Demographics by School.

Elementary School[a]	Hawaiian	Filipino	Samoan	Black	Asian[b]	Hispanic	White[c]	Others[d]
Kamaile	60%	7%	8%	2%	2%	2%	3%	15%
Pearl City	27%	25%	5%	8%	10%	4%	10%	12%
Kailua	45%	9%	3%	2%	7%	6%	21%	7%
Laie	30%	1%	27%	0%	3%	2%	19%	19%
Kaleiopu'u	14%	51%	4%	2%	10%	2%	6%	10%
Maunawili[e]	56%	4%	2%	1%	6%	2%	13%	16%
Waikele[e]	10%	34%	1%	2%	13%	1%	6%	31%
Jefferson (Oregon)	0%	0%	0%	1%	6%	7%	84%	1%
Northwest Indian Education Program (Oregon)	0%	0%	0%	0%	0%	0%	0%	100%
Hana	83%	1%	1%	0%	2%	2%	8%	3%
August Ahrens	5%	78%	5%	1%	3%	0%	1%	8%
Keaukaha[e]	85%	1%	0%	0%	1%	0%	1%	11%
Ahuimanu	48%	4%	1%	1%	19%	1%	17%	10%
Princess Nahienaena	20%	43%	1%	1%	5%	14%	4%	12%
Waipahu	10%	32%	22%	2%	2%	1%	1%	31%
Lincoln	37%	8%	1%	3%	28%	3%	6%	16%

[a]All sites are in Hawaii unless otherwise noted.
[b]Asian includes Chinese, Indo-Chinese, Japanese, and Korean.
[c]White includes Portuguese, but does not include Hispanic.
[d]Other includes Native Americans, Pacific Islanders (except Samoans), and all other races.
[e]Electronic clicker data were not collected at these events due to equipment malfunction.

coral reef degradation, and ocean acidification, so it is essential to train local geoscientists in these communities.

Achieving these goals in Hawaii necessarily entails involving families and communities. Throughout history and continuing today, NHFPI families and communities have exerted tremendous influence on educational and career decisions, to a much greater extent than in Western communities (Comer and Hayes, 1991; Epstein 1995). The Pohnpeian proverb, "The contributions of each family member contribute to the betterment of the community," is widely applicable across the Pacific (Onikama *et al.*, 1998). Attracting NHFPI students to geoscience fields — and communicating that geoscience is valuable and relevant — can only happen with family and community buy-in.

Although designed for Hawaii's students in grades 3–6, the Ocean FEST model is widely applicable to other audiences. Across the nation and across cultures, research has shown that family involvement in education significantly and positively impacts a wide range of outcomes from the earliest childhood years through high school. Benefits include improved short-term grades and long-term academic achievement, higher attendance levels, decreased drop-out levels, increased concentration, and improved attitudes such as motivation, confidence and self-esteem (e.g., Keith *et al.*, 1986; Steinberg *et al.*, 1992; Henderson and Berla, 1994; Epstein, 1995; AAAS, 1996; Hoover-Dempsey and Sandler, 1997; Trusty and Lampe, 1997; Lazar *et al.*, 1999; Gonzalez-DeHass *et al.*, 2005). Parental involvement is particularly important in STEM education, where parents' attitudes toward math and science, whether positive or negative, are frequently passed along to the next generation (e.g., Shymansky *et al.*, 2000). Hands-on activities have been found to be an effective way of involving parents in their children's science education (e.g., AAAS, 1996), and discrepant events (that is, science experiments with surprising outcomes) have found to be particularly engaging (e.g., Crockett, 2004; Lundeen, 2005).

THE OCEAN FEST PROGRAM

Program Overview

Ocean FEST family science nights feature hands-on ocean-themed science activities for students in grades 3–6 and their families. A typical event lasts 2 hours and is held in a large indoor space (such as a school cafeteria) with participants seated at tables. Pre- and post-surveys are given on content knowledge and attitudes toward marine science careers using electronic clickers. Students leave with a "science goodie bag" of supplies that will enable them to continue doing science experiments at home. Immediately preceding each Ocean FEST event, adult volunteers (usually classroom teachers) receive 30 minutes of professional development training, so they can assist with program delivery, and subsequently conduct these science activities and demonstrations with confidence in their own classrooms. A brief summary of each activity is described in the photo captions of Figs. 1–6 and in Table II. Detailed information on each activity (including background information, list of materials, instructional procedures, and alignment with science standards and benchmarks) is available from the Ocean FEST website (http://oceanfest.soest.hawaii.edu/program.htm). All activities are aligned with Hawaii Department of Education Science Content and Performance Standards (http://standardstoolkit.k12.hi.us/index.html/).

Some of these activities were created — or modified from existing activities — specifically for this Ocean FEST

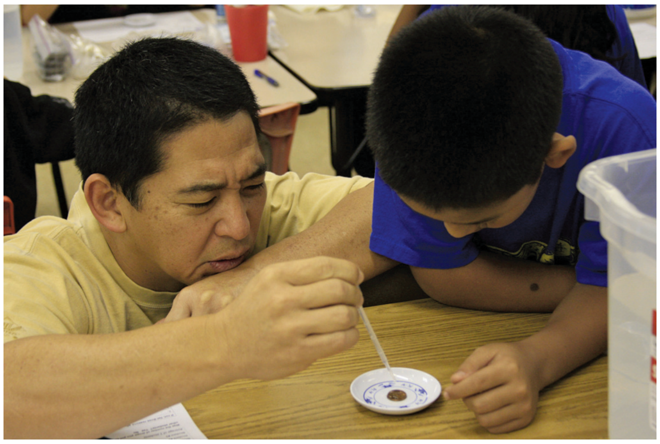

FIGURE 1: (Color online) Penny plop. As a warm-up activity during registration, students and parents each experiment to find out how many drops of water fit on a penny. Only minimal instructions are given, resulting in greatly varying outcomes. Results are averaged, compared, and discussed to illustrate the importance of making measurements in a systematic way. Key concepts include scientific method and surface tension.

TABLE II: Summary of Ocean FEST Program Activities.

Activity Name	Figure No.	Key Concepts	Relevant Research and Careers
Penny plop	1	Surface tension, scientific method	All scientific research
Cartesian divers	2	Density, pressure	HIMB[a]
Drowning Island	3	Effect of climate change on sea level rise and coastal erosion	Hawaii Coastal Geology Group[b]
Oil and water tube	4	Density; beneficial role of marine microbes as decomposers	C-MORE[c] and HIMB[a]
Ocean acidification	5	Climate change; ocean acidification; beneficial roles of corals and marine microbes	HOT,[d] HIMB,[a] and C-MORE[c]
Make a microbe	6	Density; microbial diversity; position of photosynthesizers in the water column; adaptations that protect from predators and control vertical position	C-MORE[c]

[a]HIMB: Hawaii Institute of Marine Biology http://www.hawaii.edu/HIMB/.
[b]Hawaii Coastal Geology Group http://www.soest.hawaii.edu/coasts/.
[c]C-MORE: Center for Microbial Oceanography: Research and Education http://cmore.soest.hawaii.edu/.
[d]HOT: Hawaii Ocean Time-series http://hahana.soest.hawaii.edu/hot/.

program. Others are "tried and true" activities that have been used by large numbers of educators, making it difficult to determine the original source. *Penny Plop* (Fig. 1) was based on http://scienceclub.org/sdl/penny.txt. *Cartesian Divers* (Fig. 3) and *Oil and Water Tube* (Fig. 4) are described on teachersource.com (also see references therein). *Make a Microbe* (Fig. 6) was borrowed from http://www.sea.edu/academics/k12.aspx?plan=sinkingraces. *Coral Sand and Vinegar* (Fig. 5) was adapted from similar activities (e.g., http://www.hawaii.edu/gk-12/evo/laurar.sand.htm). We created *Drowning Island* (Fig. 2) without consulting any sources, but these concepts are very basic so it would not be surprising to learn if other educators independently created similar activities.

FIGURE 2: (Color online) Cartesian divers. Cartesian divers show how pressure can affect density. Divers are pipettes filled with both air and water, so they are just slightly less dense than water. Thus, the diver floats when placed in a plastic bottle filled with water. However, if you squeeze the bottle, the diver sinks. Release and the diver floats again. Can you figure out why? This activity can be related to scuba diving, and therefore to careers in marine biology with HIMB.

Program Themes

The Ocean FEST program uses the marine environment as a "hook" to explore important science concepts and conservation topics. Developed for Native Hawaiians, Filipinos, and Pacific Islanders, the program emphasizes marine science and conservation for island communities. Program themes include ocean properties, climate change and sea level rise, coral reef ecosystems, marine microbes, and marine science careers. The evening program begins with the introduction of the scientific method through an activity that encourages inquiry and scientific thinking (Fig. 1). Subsequently, ocean properties such as density, waves, and currents are explored through a series of hands-on activities in the context of the scientific method and current environmental issues (Figs. 2–6). Activities are designed so students can see how globally important issues (e.g., climate change and ocean acidification) have local effects (e.g., sea level rise, coastal erosion, coral bleaching) which are particularly relevant to island communities. Using hands-on examples, demonstrations, and authentic research data, students and their families come to understand how climate change and the ocean are inextricably linked.

FIGURE 3: (Color online) Drowning island. Students are given a model of the earth with a large blue "ocean" and a smaller brown area to represent land. First, they make an island out of clay, and then put two plastic houses on their island. Teachers place ice cubes on the land area. During the course of the evening event, students see what happens to their real estate as the "glaciers" melt due to climate change. The effects of climate change on sea level rise and coastal erosion are discussed using local examples based on the research of the Hawaii Coastal Geology Group. Relevant geoscience careers are incorporated into this demonstration as well.

Program content is based on research currently being conducted in Hawaii by C-MORE, HIMB, the HOT program, and the Hawaii Coastal Geology Group (Table II). Much of this research is directly relevant to Hawaii and Hawaiian culture. For example, HIMB entered into a Memorandum of Agreement with the National Marine Sanctuary Program to conduct ecosystem-based research in the Papahanaumokuakea Marine National Monument, Northwestern Hawaiian Islands (NWHI). Papahanaumokuakea is of great cultural importance to Native Hawaiians with significant cultural sites found on the islands of Nihoa and Mokumanamana. Through this partnership, HIMB provides conservation science helping to inform the management of this culturally significant environment.

Career Component

The Ocean FEST program includes a culturally relevant career component, designed to introduce students — and importantly, their teachers and family members — to a broad range of earth and ocean science careers and their benefits to the local community. Many local students are discouraged from pursuing geoscience careers because of a common misconception that these careers do not benefit the Hawaiian community (as opposed to, for example, the health profession). Throughout the program, we emphasize Hawaii's critical need for geoscientists. We also share the various educational pathways that can lead to ocean and earth science careers, and connect students with local geoscience and STEM opportunities including other marine science education programs, science fairs, and programs specifically geared toward NHFPI students. We involve minority geoscience students as teaching assistants and in our promotional literature. These students can encourage the elementary school students to pursue geoscience careers by serving as role models while communicating the environmental, societal, and financial benefits of such careers to their parents and teachers.

FIGURE 4: (Color online) Oil and water tube. First, students add a capful of water into an oil-filled tube, and learn how this relates to oil spills (the less dense oil floats). Microbes are introduced as the planet's primary decomposers: some even eat oil! Next, students add colored effervescent tablets to their tubes. The resulting CO_2 bubbles dissolve in water and form carbonic acid. This provides an excellent segue to ocean acidification, and current research by Hawaii Ocean Time-series (HOT) and C-MORE.

Teacher Professional Development

Each Ocean FEST event is preceded by professional development training for the classroom teachers and other volunteers who serve as teaching assistants during the event. During this 30-minutes training session, we review each activity, covering safety issues and key "take-home" science concepts. Recommended pedagogical practices will also be shared, such as beginning an activity by exploring participant ideas and unraveling misconceptions, and then helping the student build a more accurate set of beliefs through hands-on experimentation with discrepant activities (e.g., Crockett 2004; Lundeen, 2005). The training is designed to empower teachers so they can confidently assist during the event, as well as bring the activities into their own classrooms. A Teacher Guide providing background information, list of materials (including ordering information), and a standard-based lesson plan for each activity is available online (http://oceanfest.soest.hawaii.edu/

FIGURE 5: (Color online) Ocean acidification. Students add vinegar to carbonate sand, watch the sand bubble up, and infer the sand is dissolving. A discussion follows on the threats posed by an acidifying ocean to coral reefs and calcareous microbes. This activity reinforces the importance of coral reefs and microbes both globally and locally, including examples from the Northwestern Hawaiian Islands based on HIMB research.

FIGURE 6: (Color online) Make a microbe. Throughout the evening, students learn of the critical importance of marine microbes: they form the base of the marine food web, they produce about 50% of the oxygen we breathe, and they regulate the climate by consuming carbon dioxide. This culminating activity begins with students viewing images of — and discussing — the various adaptations that microbes have to control their position in the water column and to protect themselves from predators (e.g., flagella, spines, protective shells). Then, students make their own microbes out of various craft materials. Their goal is to make a microbe that can protect itself from predators that is either neutrally buoyant or sinks very slowly through the water column. Tubs of water are provided on each table to test buoyancy, enabling students to continually adjust the density of their microbe by adding, removing or reshaping features. The activity ends with a "sinking race," where the goal is to lose the race: that is, to sink very slowly through the water column.

downloads/ocean_fest_teacher_guide.pdf), and a hard copy is given to the school coordinator.

Program Staffing and Coordination

The project team is comprised of scientists and educators from C-MORE, HIMB, and the Hawaii Space Grant Consortium, which has been conducting space-themed family science events for many years. Key partners include Hawaii's marine science education centers and elementary schools, at which most of the events occur and are coordinated.

We plan to offer twenty Ocean FEST events annually in Hawaii. Priority is given to Title I schools, schools that serve NHFPI and other underrepresented groups, as well as those in geographically underserved areas. Each event is coordinated by a teacher or administrator at the host venue. The school coordinator is responsible for providing a large open space such as a school cafeteria, signing up students each with an accompanying adult (such as a parent, grandparent or older sibling) and signing up a minimum of eight volunteers (usually classroom teachers) to assist with the event. Such event coordination serves both to reduce our administrative burden and to develop school infrastructure for planning future events. Two weeks before each event, the school closes registration and advises the final participant numbers, so we can prepare adequate materials, supplies, and staffing.

Implementation and Reproducibility

All hands-on activities are sufficiently "low-tech" to be reproducible at home, in the classroom, or in informal science education settings. Interested educators can self-train by reviewing the online teacher guide and contacting fest@soest.hawaii.edu with any questions. All public school educators, regardless of whether they attended a scheduled Ocean FEST event, are eligible to apply for Grants for Education in Microbial Science (GEMS) to purchase supplies to conduct Ocean FEST activities in their classrooms or informal education venues (http://cmore.soest.hawaii.edu/education/teachers/gems.htm).

Although designed for Hawaii's students in grades 3–6, this ocean-themed program can be effective with a wide range of audiences. To demonstrate this, we conducted two Ocean FEST events in Oregon (Table I). One event was held at Jefferson elementary school in Corvallis, a middle-class school with 84% of the student body being white. The second event was held in Portland at the Indian Education Program Title VII Northwest Regional Education Service District in collaboration with the Coastal Margins: Observations and Predictions (C-MOP) National Science Foundation Center; 100% of participants at this event were Native Americans. The latter event featured Ocean FEST science activities, Native American storytelling and traditional foods. Many of the program themes (e.g., families learning together, the importance of protecting the environment) resonated with this audience.

Educators wishing to use these activities in the classroom can build an entire lesson around a single activity. Detailed, standards-based lesson plans are provided in the online teacher guide. This guide also includes extensions, which are designed, in part, to raise these activities to a more advanced level. For example, one of the extensions to

TABLE III: Summary of Survey Data Collected from Adult Participants and Volunteers. Total Number of Respondents is 425, Although Not Every Respondent Answered Every Question.

	1 Poor	2 Fair	3 Average	4 Good	5 Excellent	Mean Rating[a]
How would you rate the program overall?	0	1	3	77	312	4.8
Please rate the following statements:	**1 Strongly disagree**	**2 Disagree**	**3 Unsure**	**4 Agree**	**5 Strongly agree**	**Mean rating[b]**
The *science activities* were fun & interesting.	1	0	1	87	333	4.8
The *instructors* were dynamic & knowledgeable.	1	0	6	88	330	4.8
The *slides and visuals* were useful.	1	1	7	103	307	4.7
The event was well organized and well paced.	2	1	6	87	322	4.7
Please rate the following statements:	**1 Strongly disagree**	**2 Disagree**	**3 Unsure**	**4 Agree**	**5 Strongly agree**	**Mean rating[b]**
Because of the Ocean FEST program...						
I am more knowledgeable about the relevance of marine science to my life.	1	5	12	151	256	4.5
I am more knowledgeable about the relevance of marine science to society.	1	5	11	151	256	4.5
I am more knowledgeable about the environmental significance of microbes.	1	3	9	122	288	4.6
I would like to learn more about Hawaii's marine environment.	0	2	18	133	265	4.6
I have a better understanding of global climate change.	1	8	16	149	246	4.5
I am more interested in my child obtaining a college degree in a science discipline	0	8	76	110	202	4.3

[a]Mean ratings range from 1 (poor) to 5 (excellent).
[b]Mean ratings range from 1 (strongly disagree) to 5 (strongly agree).

the *Cartesian Diver* activity described in Fig. 2 has students calculate the rate at which the diver rises and sinks, which is ideal for middle school students.

RESULTS: PROGRAM ASSESSMENT

Formative Evaluation

Formative evaluation occurs in several ways. First, presenters self-reflect in a debriefing session after each event. Second, two educational specialists were hired as consultants to observe six events and provided ongoing oral feedback regarding content, instruction, visuals, and event logistics. Their feedback was incorporated in "real time," and the program was revised continually throughout the year. Third, an email is sent to each school coordinator following each event to actively solicit feedback regarding event logistics. Finally, following each event, parents, teachers, and other adult volunteers complete an anonymous written survey regarding program content and instruction.

The survey results received from 425 adult respondents are presented in Table III and briefly summarized here. Participants were asked to rate their agreement with a series of statements on a Likert scale, where 1 = strongly disagree and 5 = strongly agree. They found the science activities fun and interesting (mean rating = 4.8), the instructors dynamic and knowledgeable (4.8), the slides and visuals useful (4.7), and the event well-organized and well paced (4.7). Because of the Ocean FEST program, participants reported being more knowledgeable about the relevance of marine science to their lives (4.5) and to society (4.5), being more knowledgeable about the

TABLE IV: Ocean FEST Site Locations, Dates, and Participant N Sizes Where Electronic Clicker Data Were Collected.

Site[a]	Date	Valid N[b]
Kamaile Elementary	November 10, 2009	29
Pearl City Elementary	November 16, 2009	27
Kailua Elementary	December 2, 2009	20
Laie Elementary	January 13, 2010	38
Kaleiopuu Elementary	January 21, 2010	42
Jefferson Elementary (Oregon)	February 22, 2010	54
Northwest Indian Education Program (Oregon)	March 1, 2010	22
Hana Elementary	March 5, 2010	19
August Ahrens Elementary	April 1, 2010	34
Ahuimanu Elementary	April 19, 2010	32
Princess Nahienaena Elementary	April 29, 2010	32
Waipahu Elementary	May 5, 2010	18
Lincoln Elementary	May 11, 2010	39
Total		406

[a]All sites are in Hawaii unless otherwise noted.
[b]Number of students who completed both the pre- and postsurvey.

TABLE V: Student Survey Questions.

Question Topic	Answer A	Answer B
1. Density	A dense object is more likely to sink.[a]	A dense object is more likely to float.
2. Microbes	Most microbes are bad for us.	Most microbes are good for us.[a]
3. Ocean acidification	Acid causes corals and certain microbes to get darker.	Acid causes corals and certain microbes to dissolve.[a]
4. Sea level rise	Global warming is causing sea levels to rise.[a]	Global warming is causing sea levels to fall.
5. Careers	Being a marine scientist is fun and exciting.[a]	Being a marine scientist is lame and boring.

[a]Denotes correct or desired answers.

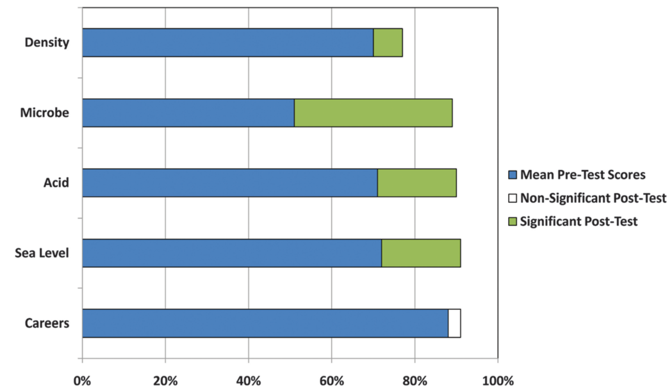

FIGURE 7: (Color online) Results of statistical analysis of student surveys for individual questions. This figure presents means of pre- and post-survey scores for individual questions on the student surveys, and notes whether any gains shown on the postsurveys were statistically significant at the 0.01 level. All five questions showed a positive mean gain from pre- to post-test, ranging from 0.02 and 0.38. All but one gain were found to be statistically significant at the 0.01 level.

environmental significance of microbes (4.6), and having a better understanding of global climate change (4.5). Because of the Ocean FEST program, respondents reported that they would like to learn more about Hawaii's marine environment (4.6) and are more interested in their child obtaining a college degree in science (4.3). Overall, participants gave the program an overall mean rating of 4.8 on a five-point scale, where 1 = poor and 5 = excellent.

Summative Evaluation

We performed a summative evaluation at thirteen of the sixteen events using hand-held electronic clickers (Table IV); no data were collected at three sites due to technical problems. Clickers are widely used in real-time electronic polling of audiences; they collect learner input for instant display on a computer monitor or LCD projector. During Ocean FEST, clickers (each with a unique identification number) were used to collect information on students' content knowledge and attitudes towards marine science careers through five multiple-choice questions (Table V). Questions were both projected visually and read aloud. Two of these questions are on C-MORE-related science content (microbes and ocean acidification), two questions are on general marine science knowledge (density and sea level rise), and one question asks about career attitudes.

External evaluators were engaged to compare the pre- and postsurveys. A total of 406 student respondents' raw scores were recoded into a dichotomous variable indicating whether the participant answered the question correctly (1) or incorrectly (0). A total score for each respondent was then computed for both the pre- and post-survey by summing the total number of correct answers (numerator) and dividing by the number of questions (denominator). The resulting score is a number between 0 and 1. The McNemar statistic (similar to a paired t-test, but better suited to binary data), was used to calculate the significance of change between pre- and postsurvey total scores for each question (Table VI and Fig. 7).

All four content questions showed positive mean gains, ranging from 0.08 to 0.38. Each of these gains are statistically significant at the 0.01 level (that is, $p < 0.01$), with the greatest gain associated with the microbe question. Before the event, only 51% of students knew that most microbes are good for us, while 89% of students had the correct answer in the post-survey. The fifth question concerning career attitudes showed a small increase in interest in marine science careers (from 88% pretest to 91% post-test) but this was not found to be statistically significant. This perhaps is not surprising when such a high number express interest in marine science careers prior to the event.

TABLE VI: Statistical Analysis of Individual Test Questions on Pre- and Post-Tests.

Question[a]	N	Pre-Test[b]	Post-Test[b]	Difference[c]	p-Value[d]	p<0.01[e]
Density	392	0.70 (0.46)	0.77 (0.42)	0.08 (0.55)	0.009	Yes
Microbes	394	0.51 (0.50)	0.89 (0.32)	0.38 (0.57)	0.000	Yes
Ocean acidification	316	0.71 (0.45)	0.90 (0.30)	0.18 (0.54)	0.000	Yes
Sea level rise	392	0.72 (0.45)	0.91 (0.29)	0.19 (0.51)	0.000	Yes
Careers	396	0.88 (0.32)	0.91 (0.29)	0.02 (0.34)	0.243	No

[a]Questions given on pre- and post-tests. Please see Table V for exact question wording.
[b]Percentage of answers to this question that are correct, followed by standard deviation (given in parentheses).
[c]Difference between pre- and post-test percentages, followed by standard deviation (given in parentheses).
[d]p-value, rounded to the third decimal place, indicating statistical significance.
[e]Determination of whether the difference is statistically significant at the 0.01 level (that is, p<0.01).

TABLE VII: Statistical Analysis of Categories of Test Questions on Pre- and Post-Tests.

Category[a]	N	Pre-Test[b]	Post-Test[b]	Difference[c]	p-Value[d]	p<0.01[e]
C-MORE-related	309	0.60 (0.34)	0.89 (0.24)	0.28 (0.39)	0.000	Yes
General ocean science	380	0.71 (0.32)	0.84 (0.26)	0.14 (−0.14)	0.000	Yes
Careers	396	0.88 (0.32)	0.91 (0.29)	0.02 (0.34)	0.243	No

[a]Categories of question types.
[b]Percentage of answers to questions in this category that are correct, followed by standard deviation (given in parentheses).
[c]Difference between pre-test and post-test percentages, followed by standard deviation (given in parentheses).
[d]p-value, rounded to the third decimal place, indicating statistical significance.
[e]Determination of whether the difference is statistically significant at the 0.01 level (that is, $p<0.01$).

Table VII and Fig. 8 summarize the statistical analysis by question type. Questions on C-MORE-related content (microbes and ocean acidification) showed the greatest gain, from 60% pretest to 89% post-test, largely reflecting the increase in knowledge gained about the importance of marine microbes. Students also reported a significant knowledge gain in general ocean science content (density and sea level rise), from 71% pretest to 84% post-test. As discussed above, the career category (comprised of a single question) showed a small increase in interest in marine science careers which was not found to be statistically significant at the 0.01 level.

CONCLUSIONS AND FUTURE WORK

Encouraged by these evaluation results, we plan to expand the program in several ways. First, we will encourage school coordinators who have been previously trained (i.e., by attending a pre-event professional development training and serving as a teaching assistant during an event) to consider organizing their own events. We will support them by providing supplies, logistical support, as well as content support. Second, we will conduct a series of 2-hour training workshops for teachers who have not attended events in both content and logistics. For those teachers interested in self-training, we have created a website (http://oceanfest.soest.hawaii.edu) containing all the information required to run an Ocean FEST event, including details of each activities, background information, PowerPoint presentation, and logistical information. All Ocean FEST materials can be freely used for educational, noncommercial purposes, and we actively encourage marine science educators to integrate these materials into their own formal or informal educational programs.

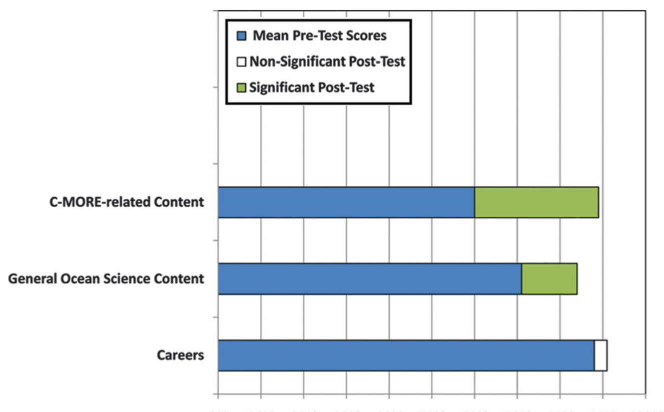

FIGURE 8: (Color online) Results of statistical analysis of student surveys for question types. This figure presents means of pre-survey and post-survey scores for categories of questions on the student surveys, and notes whether any gains shown on the postsurveys were statistically significant at the 0.01 level. The five survey questions shown in Table V are grouped into categories: C-MORE-related content (questions 2 and 3); general ocean science content knowledge (questions 1 and 4); and career attitudes (question 5). All three categories showed a positive mean gain from pre- to post-test, ranging from 0.02 to 0.38. The gains in both content knowledge areas were found to be significant at the 0.01 level, but the increase in marine science career interest was not.

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